

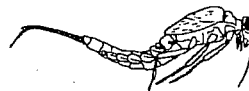
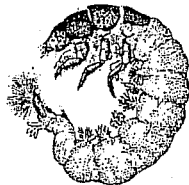
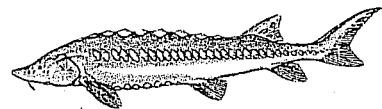
**IDENTIFICATION OF THE INSTREAM FLOW REQUIREMENTS  
FOR ANADROMOUS FISH IN THE STREAMS WITHIN  
THE CENTRAL VALLEY OF CALIFORNIA**

**Annual Progress Report  
Fiscal Year 2004**

U.S. Fish and Wildlife Service  
Sacramento Fish and Wildlife Office  
2800 Cottage Way, Room W-2605  
Sacramento, California 95825



Prepared by staff of  
The Energy Planning and Instream Flow Branch



## PREFACE

The following is the third annual progress report prepared as part of the Central Valley Project Improvement Act Instream Flow Investigations, a 6-year effort which began in October, 2001.<sup>1</sup> Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service (Service) after consultation with the California Department of Fish and Game (CDFG). The purpose of this investigation is to provide reliable scientific information to the Service's Central Valley Project Improvement Act Program to be used to develop such recommendations for Central Valley streams and rivers.

The field work described herein was conducted by Ed Ballard, Mark Gard, Bill Pelle, Rick Williams, Matt McCormack, Laurie Stafford, Brandon Thompson, Sarah Giovannetti, Josh Grigg, Ethan Jankowski, Debbie Giglio, and Rich DeHaven.

Written comments or questions about this report or these investigations should be submitted to:

Mark Gard, Senior Fish and Wildlife Biologist  
Energy Planning and Instream Flow Branch  
U.S. Fish and Wildlife Service  
Sacramento Fish and Wildlife Office  
2800 Cottage Way, Room W-2605  
Sacramento, California 95825

---

<sup>1</sup> This program is a continuation of a 7-year effort, also titled the Central Valley Project Improvement Act Instream Flow Investigations, which ran from February 1995 through September 2001.

## INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late-fall, winter, and spring), steelhead trout, and white and green sturgeon. In June 2001, the Sacramento Fish and Wildlife Office (Service), Energy Planning and Instream Flow Branch prepared a study proposal to use the Service's Instream Flow Incremental Methodology (IFIM) to identify the instream flow requirements for anadromous fish in selected streams within the Central Valley of California. The proposal included completing instream flow studies on the Sacramento and Lower American Rivers and Butte Creek which had begun under the previous 7-year effort, and conducting instream flow studies on other rivers, with the Yuba River selected as the next river for studies. The last report for the Lower American River study was completed in February 2003 and the final report for the Butte Creek study was completed in September 2003. In 2004, Clear Creek was selected as an additional river for studies.

The Sacramento River study was planned to be a 7-year effort originally scheduled to be concluded in September 2001. Specific goals of the study are to determine the relationship between streamflow and physical habitat availability for all life stages of chinook salmon (fall, late-fall, winter-runs) and to determine the relationship between streamflow and redd dewatering and juvenile stranding. The study components include: 1) compilation and review of existing information; 2) consultation with other agencies and biologists; 3) field reconnaissance; 4) development of habitat suitability criteria (HSC); 5) study site selection and transect placement; 6) hydraulic and structural data collection; 7) construction and calibration of reliable hydraulic simulation models; 8) construction of habitat models to predict physical habitat availability over a range of river discharges; and 9) preparation of draft and final reports. The first six study components were completed by October 2001. The Fiscal Year (FY) 2004 Scope of Work (SOW) identified study tasks to be undertaken. These included: construction of hydraulic models (study component 7), construction of habitat models (study component 8), and preparation of draft and final reports (study component 9).

The Yuba River study is a 4-year effort, the goals of which are to determine the relationship between stream flow and physical habitat availability for all life stages of chinook salmon (fall- and spring-runs) and steelhead/rainbow trout and to identify flows at which redd dewatering and juvenile stranding conditions occur. The study started with the location and counting of spring-run chinook salmon redds during September 2001 and the collection of fall-run chinook salmon spawning HSC during November-December 2001. Collection of spawning criteria data for fall- and spring-run chinook salmon and steelhead/rainbow trout was completed by April 2004. Field work to determine the relationship between habitat availability (spawning) and streamflow for spring-run and fall-run chinook salmon and steelhead/rainbow trout was continued in FY 2004 and will be completed in FY 2005. This field work included hydraulic and structural data collection. In FY 2004, field work to determine the relationship between habitat availability (juvenile rearing) and streamflow for spring-run and fall-run chinook salmon and steelhead/rainbow trout was conducted on the study sites selected in FY 2003. In addition, the process of gathering HSC data for juvenile rearing continued.

The Clear Creek study is a 5-year effort, the goals of which are to determine the relationship between stream flow and physical habitat availability for all life stages of chinook salmon (fall- and spring-run) and steelhead/rainbow trout. There will be three phases to this study based on the life stages to be studied and the number of reaches delineated for Clear Creek from downstream of Whiskeytown Reservoir to the confluence with the Sacramento River<sup>2</sup>. Spawning habitat study sites for the first phase of the study were selected that encompassed the upper two reaches of the creek. Field work to determine the relationship between habitat availability (spawning) and streamflow for spring-run chinook salmon and steelhead/rainbow trout was begun in FY 2004. This field work included hydraulic and structural data collection. In addition, staff of the Red Bluff Fish and Wildlife Office have been collecting HSC data for spring-run chinook salmon and steelhead/rainbow trout spawning.

The following sections summarize project activities between October 2003 and September 2004.

## **SACRAMENTO RIVER**

### **Hydraulic Model Construction and Calibration**

#### ***Juvenile chinook salmon stranding areas***

Stranding flows have been determined for 88 of the 108 stranding sites. Stranding areas have been determined for 102 of the 108 stranding sites. The stranding flows and areas for the remaining sites will be determined in FY 2005, and a final report on juvenile chinook salmon stranding sites will be completed by September 2005.

#### ***Chinook salmon spawning habitat***

The topographic data for the 2-D model (contained in bed files) is first processed using the R2D\_Bed software, where breaklines are added to produce a smooth bed topography. The resulting data set is then converted into a computational mesh using the R2D\_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated.

The Physical Habitat System (PHABSIM) transect at the downstream end of each site is calibrated to provide the Water Surface Elevation's (WSEL) at the downstream end of the site used by River2D. The PHABSIM transect at the upstream end of the site is calibrated to provide the water

---

<sup>2</sup> There are three reaches: the upper alluvial reach, the canyon reach, and the lower alluvial reach. Spring-run chinook salmon and steelhead spawn in the upper two reaches, while fall-run chinook salmon spawn in the lower reach.

surface elevations used to calibrate the River2D model. The initial bed roughnesses used by River2D are based on the observed substrate sizes and cover types. A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the upstream end of the site match the WSEL predicted by the PHABSIM transect at the upstream end of the site<sup>3</sup>. The River2D model is run at the flows at which the validation dataset was collected, with the output used in GIS to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover. The River2D model is also run at the simulation flows to use in computing habitat.

All data for the six fall-run chinook salmon spawning sites between Battle Creek and Deer Creek have been compiled and checked. PHABSIM data decks and hydraulic calibration have been completed for the upstream and downstream transects for all six sites. Bed files and computational meshes have been completed for all six sites. Construction and calibration of the 2-D models and production runs for all of the simulation flows have been completed for two sites, and are in process for a third site. Construction and calibration of 2-D models are in process for the remaining three sites and production runs for the remaining sites will be completed in FY 2005.

### ***Juvenile chinook salmon rearing habitat***

All of the data for the rearing sites between Keswick Dam and Battle Creek have been compiled and checked. PHABSIM data decks have been created and hydraulic calibration has been completed for the upstream and downstream transects for all of the rearing sites between Keswick Dam and Battle Creek. Bed files, computational meshes for the 2-D modeling program, calibration of the two-dimensional hydraulic models, and production runs for all of the simulation flows have been completed for all of the 17 rearing sites between Keswick Dam and Battle Creek.

## **Habitat Suitability Criteria Development**

### ***Juvenile chinook salmon rearing***

Data collection for fry and juvenile rearing criteria was completed in FY 2001. Development of fry and juvenile rearing criteria was completed in FY 2003.

### ***Chinook salmon spawning***

HSC data were not collected for the six study sites on the Sacramento River between Battle Creek and Deer Creek. HSC previously developed by the Service on the Sacramento River for fall-run chinook salmon spawning (FWS 2003) will be used for these sites.

---

<sup>3</sup> This is the primary technique used to calibrate the River2D model.

### ***Macroinvertebrate criteria***

We are developing a second set of juvenile chinook salmon HSC - one based on food supply rather than physical habitat. Specifically, we are developing HSC for macroinvertebrate biomass and diversity. The criteria we develop will be run on the juvenile rearing site habitat models to predict the relationship between flow and habitat area for macroinvertebrate biomass and diversity. We completed our sampling for macroinvertebrate criteria in FY 2001, with a total of 75 macroinvertebrate samples (22 in riffles, 20 in runs, 13 in pools and 20 in glides). Processing of samples, and computation of biomass and diversity represented by each sample, was completed under contract in July of 2004. HSC will be developed for macroinvertebrate production and diversity as determined by depth, velocity, and substrate size based on the biomass and diversity determined for the samples. Given the stratification of the sampling by depth, velocity and substrate, the 75 samples collected should be sufficient to generate HSC. We have received the results from the contractor and will develop the macroinvertebrate criteria in FY 2005. These criteria will be applied to the 2-D modeling results of the rearing sites between Keswick Dam and Battle Creek to generate flow-habitat relationships. A draft report will be issued on this work by September 2005.

## **Habitat Simulation**

### ***Juvenile chinook salmon rearing***

Using the Sacramento River juvenile chinook salmon rearing criteria developed in FY 2003, rearing habitat was computed over a range of discharges in FY 2004 for 14 of the 17 rearing sites. A draft report on flow-habitat relationships for fall, late-fall and winter-run chinook salmon rearing between Keswick Reservoir and Battle Creek was completed by the end of December 2004.

### ***Chinook salmon spawning***

Fall-run chinook salmon spawning habitat will be computed over a range of discharges in FY 2005 for the six study sites between Battle Creek and Deer Creek. A draft report on flow-habitat relationships for spawning between Battle Creek and Deer Creek should be completed by September 2005<sup>4</sup>.

---

<sup>4</sup> A final report on spawning between Keswick Dam and Battle Creek was issued in February 2003.

# YUBA RIVER

## Habitat Suitability Criteria Development

### *Spawning*

#### Methods

HSC are used within 2-D habitat modeling to translate hydraulic and structural elements of rivers into indices of habitat quality. On November 18-20, 2003, we collected fall-run chinook salmon spawning criteria data in deep water habitat (depths exceeding 3.0 feet). We surveyed between the Narrows and Daguerre Dam and from Daguerre Dam downstream to the Plantz study site. This data will be combined with the data collected in previous years for HSC development. Depth, velocity and substrate size were measured for each redd. The location of each redd was also recorded using GPS. In most cases, depths and velocities were measured by hand using a wading rod and Marsh-McBirney<sup>R</sup> Model 2000 flow meter. However, depths of two redds required the use of an Acoustic Doppler Current Profiler (ADCP) to measure depth and velocity. Water visibility was sufficient to sample most areas by visual observation above the water surface. Our underwater video system was used to search for redds in the few areas where redds could not be located by visual observation above the water surface. Flows in the river upstream of Daguerre Dam from the beginning of fall-run spawning (October 1) until data collection for this portion of the river was completed on November 20, 2003, fluctuated between 746-1,105 cfs (Figure 1). Flows in the river downstream of Daguerre Dam from the beginning of fall-run spawning through the end of data collection fluctuated between 527-692 cfs (Figure 1). The unstable nature of the flows in both portions of the river resulted in some uncertainty that the measured depths and velocities were the same as those present at the time of redd construction.

We collected HSC data for steelhead/rainbow trout on April 5-8, 2004. We were unable to collect HSC data for steelhead/rainbow trout during the months of February-March due to high water and poor visibility conditions. We surveyed shallow and deep water habitat from the vicinity of the Island site upstream to approximately 0.5 mile upstream of the Rosebar site. No survey work was conducted downstream of Daguerre Dam based on the minimal spawning activity observed there in previous years. The steelhead/rainbow trout spawning criteria data collected consisted of habitat suitability data (depth, velocity and substrate), redd widths and lengths, the minimum depth of the tailspill, and a count of the number of redds in each distinct spawning area. This data will be combined with data collected in previous years for developing HSC. We also recorded the percentage of redd superimposition and periodically recorded water temperature. Upstream of Daguerre Dam, flows fluctuated moderately between approximately 2,142-2,860 cfs during the one-month period prior to the April 5-8, 2004, data collection (Figure 2), resulting in some uncertainty that the measured depths and velocities were the same as those present at the time of redd construction. This uncertainty is somewhat reduced because 16 of the redds had fish on them, and thus were likely constructed within a few days of measurement. We are assuming that we would not classify redds as fresh, and thus take measurements on them, if they are more than one month old.

Figure 1  
2003 Yuba River Fall-run Chinook Salmon Spawning Flows

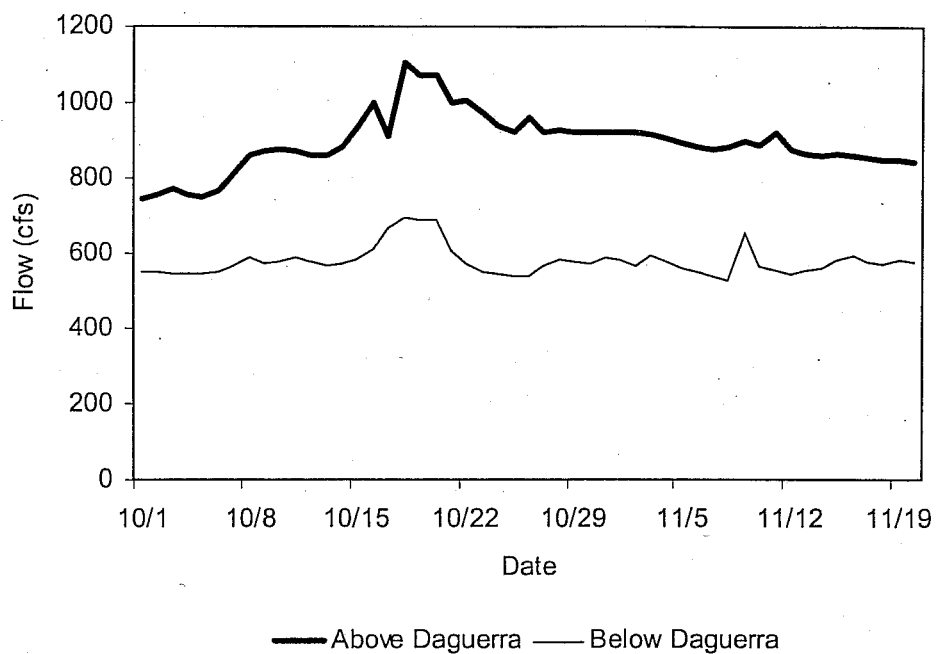
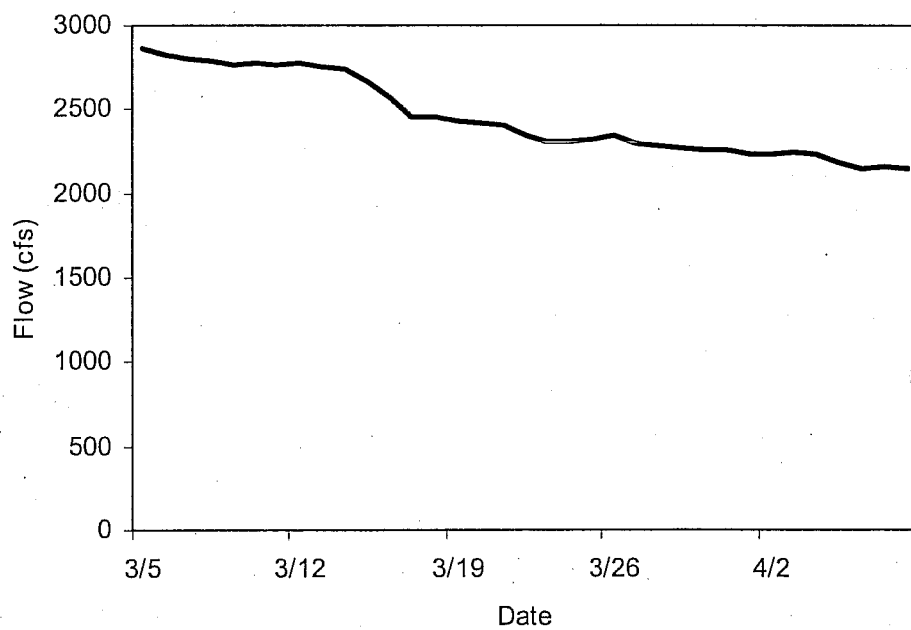


Figure 2  
2004 Yuba River Steelhead/Rainbow Trout Spawning Flows Above Daguerra





For HSC data collection, all of the active redds (those not covered with periphyton growth) which could be distinguished were measured. Data were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction. This location was generally about 2 to 4 feet upstream of the pit of the redd; however it was sometimes necessary to make measurements at a 45 degree angle upstream, to the side, or behind the pit. The data were almost always collected within 6 feet of the pit of the redd. Depth was recorded to the nearest 0.1 foot (ft) and average water column velocity was recorded to the nearest 0.01 ft/second. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2 inches) at three locations: 1) in front of the pit; 2) on the sides of the pit; and 3) in the tailspill. Substrate embeddedness data were not collected because the substrate adjacent to all of the redds sampled was predominantly unembedded. The substrate coding system used is shown in Table 1.

Table 1  
Substrate Descriptors and Codes

Code	Type	Particle Size (inches)
0.1	Sand/Silt	< 0.1
1	Small Gravel	0.1 - 1
1.2	Medium Gravel	1 - 2
1.3	Medium/Large Gravel	1 - 3
2.4	Gravel/Cobble	2 - 4
3.5	Small Cobble	3 - 5
4.6	Medium Cobble	4 - 6
6.8	Large Cobble	6 - 8
8	Large Cobble	8 - 10
9	Boulder/Bedrock	> 12
10	Large Cobble	10-12

Location of redds in deep water where redds could not be located from above the water surface was accomplished by boat using underwater video. When searching for redds in deep water using underwater video, a series of parallel runs with the boat upstream within a mesohabitat unit was performed. After locating a redd in deep water, substrate size was measured using underwater video directly over the redds. Depth and water velocity was measured over the redds using the ADCP. The location of all redds (both in shallow and deep water) was recorded with a GPS unit, so that we could ensure that redds were not measured twice.

## Results

We collected HSC data for 11 deep fall-run chinook salmon redds upstream of Daguerre Dam and 4 deep redds located downstream of Daguerre Dam.

HSC data were collected for 92 steelhead/rainbow trout redds for the length of river surveyed between the Island site and habitat unit #196 (approximately 0.5 mile upstream of the Rosebar site). Due to the difficulty in distinguishing between steelhead trout and endemic rainbow trout, it was impossible to verify whether the redds were constructed by steelhead trout. Based on data collected by CDFG on fall-run chinook salmon and steelhead redds in the Lower American River, we have developed the following criteria to distinguish steelhead/rainbow trout redds from chinook salmon redds: steelhead/rainbow trout redds have a length less than 5.1 feet and a width less than 4.5 feet, while chinook salmon redds have a length greater than 5.1 feet or a width greater than 4.5 feet. These criteria correctly classified 96 percent of 129 chinook salmon redds and 53 percent of 28 steelhead redds from the Lower American River. Since our goal is to avoid classifying chinook salmon redds as steelhead redds, we feel that the above criteria are sufficiently accurate for purposes of collecting steelhead/rainbow trout spawning criteria, particularly since there appear to be relatively few late-fall-run chinook salmon in the Yuba River. However, we are classifying all redds measured in April as steelhead/rainbow trout redds, since April is after the end of late-fall-run chinook salmon spawning.

## *Juvenile Rearing*

The collection of Young of Year (YOY) chinook salmon and steelhead/rainbow trout (fry and juveniles) rearing HSC data continued during FY 2004 with surveys conducted on November 3-6, 2003, January 26-29, 2004, March 22-24, 2004, May 17-20, 2004, July 12-15, 2004, and September 20-23, 2004. Snorkel surveys were conducted along the banks, while SCUBA was employed to survey the deep water portion of the habitat units. We also collected depth, velocity, adjacent velocity<sup>5</sup> and cover data on locations which were not occupied by YOY chinook salmon and steelhead/rainbow trout (unoccupied locations). This was done so that we could apply a

---

<sup>5</sup> The adjacent velocity was measured within 2 feet on either side of the location where the velocity was the highest. Two feet was selected based on a mechanism of turbulent mixing transporting invertebrate drift from fast-water areas to adjacent slow-water areas where fry and juvenile salmon and steelhead/rainbow trout reside, taking into account that the size of turbulent eddies is approximately one-half of the mean river depth (Terry Waddle, USGS, personal communication), and assuming that the mean depth of the Yuba River is around 4 feet (i.e., 4 feet x  $\frac{1}{2}$  = 2 feet). This measurement was taken to provide the option of using an alternative habitat model which considers adjacent velocities in assessing habitat quality. Adjacent velocity can be an important habitat variable as fish, particularly fry and juveniles, frequently reside in slow-water habitats adjacent to faster water where invertebrate drift is conveyed. Both the residence and adjacent velocity variables are important for fish to minimize the energy expenditure/food intake ratio and maintain growth.

method presented in Rubin et. al. (1991) to explicitly take into account habitat availability in developing HSC criteria, without using preference ratios (use divided by availability).

Traditionally, criteria are created from observations of fish use by fitting a nonlinear function to the frequency of habitat use for each variable (depth, velocity, cover, adjacent velocity). One concern with this technique is what effect the availability of habitat has on the observed frequency of habitat use. For example, if cover is relatively rare in a stream, fish will be found primarily not using cover simply because of the rarity of cover, rather than because they are selecting areas without cover. Rubin et. al. (1991) proposed a modification of the above technique where habitat suitability criteria data are collected both in locations where fish are present and in locations where fish are absent. Criteria are then developed by using a nonlinear regression procedure (suited to data with a Poisson distribution) with number of fish as the dependent variable and depth, velocity, cover and adjacent velocity as the independent variables, and all of the data (in both occupied and unoccupied locations) are used in the regression. An alternative approach is to use a logistic regression procedure, with the only difference being that the dependent variable is the presence or absence of fish.

Before going out into the field, a data book was prepared with one line for each unoccupied location where depth, velocity, cover and adjacent velocity would be measured. Each line had a distance from the bank, with a range of 0.5 to 10 feet by 0.5 foot increments, with the values produced by a random number generator. In areas where we were able to sample up to 20 feet from the bank, we doubled the above distances.

When conducting snorkel surveys adjacent to the bank, one person snorkeled upstream along the bank and placed a weighted, numbered tag at each location where YOY chinook salmon or steelhead/rainbow trout were observed. The snorkeler recorded the tag number, the species, the cover code<sup>6</sup> and the number of individuals observed in each 10-20 mm size class on a Poly Vinyl Chloride (PVC) wrist cuff. Water temperature, the average and maximum distance from the water's edge that was sampled, cover availability in the area sampled (percentage of the area with different cover types) and the length of bank sampled (measured with a 300-foot-long tape) was also recorded. The cover coding system used is shown in Table 2.

A 300-foot-long tape was put out with one end at the location where the snorkeler finished and the other end where the snorkeler began. Three people went up the tape, one with a stadia rod and data book and the other two with a wading rod and velocity meter. At every 20-foot interval along the tape, the person with the stadia rod measured out the distance from the bank given in the data book. If there was a tag within 3 feet of the location, "tag within 3" was recorded on that line in the data book and the people proceeded to the next 20-foot mark on the tape, using the distance from the bank on the next line. If the location was beyond the sampling distance, based on the information recorded by the snorkeler, "beyond sampling distance" was recorded on that line and the recorder went to the next line at that same location, repeating until reaching a line with a

---

<sup>6</sup> If there was no cover elements (as defined in Table 2) within 1 foot horizontally of the fish location, the cover code was 0.1 (no cover).

Table 2  
Cover Coding System

Cover Category	Cover Code <sup>7</sup>
no cover	0.1
cobble (3-12" diameter)	1
boulder (> 1' diameter)	2
fine woody vegetation (< 1" diameter)	3
branches	4
log (> 1' diameter)	5
overhead cover (> 2' from substrate)	7
undercut bank	8
aquatic vegetation	9
rip-rap	10

distance from the bank within the sampling distance. If there was no tag within 3 feet of that location, one of the people with the wading rod measured the depth, velocity, adjacent velocity and cover at that location. Depth was recorded to the nearest 0.1 ft and average water column velocity and adjacent velocity were recorded to the nearest 0.01 ft/s. Another individual retrieved the tags, measured the depth and mean water column velocity at the tag location, measured the adjacent velocity for the location, and recorded the data for each tag number. Data taken by the snorkeler and the measurer were correlated at each tag location.

Scuba surveys of deep water mesohabitat areas were conducted by first anchoring a rope longitudinally upstream through the area to be surveyed to facilitate upstream movement by the divers and increase diver safety. Two divers entered the water at the downstream end of the rope and proceeded along the rope upstream using climbing ascenders. One diver concentrated on surveying the water below and to the side, while the other diver concentrated on surveying the water above and to the side. When a YOY salmon or steelhead/rainbow trout was observed, a weighted buoy was placed by the divers at the location of the observation. The cover code and the number of individuals observed in each 10-20 mm size class was then recorded on a PVC wrist cuff. Water temperature, cover availability in the area sampled (percentage of the area with different cover types) and the length of river sampled (measured with the electronic distance meter) were also recorded.

<sup>7</sup> In addition to these cover codes, we have been using the composite cover codes 3.7, 4.7, 5.7 and 9.7; for example, 4.7 would be branches plus overhead cover.

After the dive was completed, the ADCP was turned on (to record unoccupied depth and velocity data) as we started to pull in the rope after the dive. The boat followed the course of the dive as the rope was pulled back into the boat. If there were any observations during the dive, the ADCP was stopped 3 feet before the location of the observation and started again 3 feet after the location of the observation. For each occupied location, individuals in the boat retrieved each buoy and measured the water velocity and depth over that location with the ADCP, making at least 12 observations. For each set of data collected using the ADCP for a juvenile fish observation, the average depth and velocity are considered the depth and velocity, while the maximum velocity is considered the adjacent velocity. The ADCP was turned off at the location where the dive ended.

A random number generator was used to select ADCP measurements of depth and velocity for unoccupied locations. The number of unoccupied cells selected for each site was the lesser of either 10 percent of the total distance (feet) sampled or 30 percent of the total number of ADCP points. For the SCUBA data, cover was assigned to all of the observations in proportion to which they were observed during the dive. The adjacent velocity for each unoccupied location was the largest of the three following values: the velocity at the location immediately prior to the unoccupied location, the velocity at the unoccupied location, and the velocity at the location immediately after the unoccupied location.

All YOY chinook salmon observed have been classified by race according to a table provided by CDFG correlating race with life stage periodicity and total length. However, based on Earley and Brown (2004) and McReynolds et al.'s (2004) findings that most known spring-run chinook salmon YOY from Sacramento River tributaries would be classified as fall-run by the CDFG race table, we are considering all YOY classified by the race table as fall-run to be spring/fall-run. It is likely we would find the same results as Earley and Brown (2004) and McReynolds et al. (2004) for the Yuba River, since we have only had two observations (both yolk-sac fry) which were classified as spring-run by the CDFG race tables. Data were also compiled on the length of each mesohabitat and cover type sampled to try to have equal effort in each mesohabitat and cover type and that each location was only sampled once at the same flow (to avoid problems with pseudo-replication).

## Results

In FY-2004, we collected a total of 322 measurements of cover, depth, velocity and adjacent velocity where YOY steelhead/rainbow trout and spring/fall-run chinook salmon were observed. There were 143 observations of YOY spring/fall-run chinook salmon, and 182 observations of YOY steelhead/rainbow trout. Of the 143 YOY spring/fall-run chinook salmon observations, 109 observations were made downstream of Daguerre Dam and 34 observations were made upstream of Daguerre Dam, with only 5 of the observations made using SCUBA; the remaining observations were made near the river banks while snorkeling. There were 41 YOY spring/fall-run chinook salmon observations of <40 mm fish, 97 observations of 40-60 mm fish, 13 observations of 60-80

mm fish, and 3 observations of >80 mm fish<sup>8</sup>. Of the 182 observations of YOY steelhead/rainbow trout, 9 observations were made downstream of Daguerre Dam and 173 observations were made upstream of Daguerre Dam. All of these observations were made near the river banks while snorkeling. Of the 182 YOY steelhead/rainbow trout observations, there were 33 observations of < 40 mm fish, 145 observations of 40-60 mm fish, 20 observations of 60-80 mm fish and 4 observations of fish greater than 80 mm<sup>9</sup>. We made 1,248 measurements for unoccupied locations (1,009 in shallow areas and 239 in deep areas). Depth, velocity and adjacent velocity were measured at all 1,248 locations, and cover was recorded at all of the shallow locations and assigned as discussed above to all of the deep locations.

A total of 74 mesohabitat units (43 upstream of Daguerre Dam and 31 downstream of Daguerre Dam) have been surveyed to date. Twelve of these mesohabitat units were surveyed using SCUBA, with 70 surveyed by snorkeling<sup>10</sup>. A total of 24,750 feet of near-bank habitat and 5,995 feet of deep water habitat have been sampled to date. Table 3 summarizes the number of feet of different mesohabitat types sampled to date and Table 4 summarizes the number of feet of different cover types sampled to date.

We have developed two different groups of cover codes based on snorkel surveys we conducted on the Sacramento River: Cover Group 1 (cover codes 4 and 7 and composite [instream+overhead] cover), and Cover Group 0 (all other cover codes). We sampled 22,166 feet of Cover Group 0 and 5,816 feet of Cover Group 1 in near-bank habitat (snorkeling), and sampled 2,584 feet of Cover Group 0 and 180 feet of Cover Group 1 in mid-channel habitat (SCUBA). The collection of chinook salmon and steelhead/rainbow trout fry and juveniles (YOY) rearing HSC data will continue in FY 2005 with data collection planned every 1-2 months through the year. We will be spending particular effort on getting observations of YOY > 60 mm, since we have so few observations of these larger fish to date.

---

<sup>8</sup> These numbers total more than 143 because most of the observations included YOY of several size classes and only one measurement was made per group of closely associated individuals.

<sup>9</sup> These numbers total more than 182 because most of the observations included YOY of several size classes and only one measurement was made per group of closely associated individuals.

<sup>10</sup> Some habitat units were surveyed with both snorkeling and SCUBA.

Table 3  
Distances (feet) Sampled for YOY Salmonid HSC Data - Mesohabitat Types

Mesohabitat Type	Near-bank habitat distance sampled	Mid-channel habitat distance sampled
Bar Complex Glide	4420	300
Bar Complex Pool	3805	4140
Bar Complex Riffle	2244	0
Bar Complex Run	8631	0
Flatwater Glide	980	0
Flatwater Pool	1080	1555
Flatwater Riffle	0	0
Flatwater Run	230	0
Side-Channel Glide	399	0
Side-Channel Pool	815	0
Side-Channel Riffle	220	0
Side-Channel Run	1926	0

Table 4  
Distances (feet) Sampled for Juvenile Salmonid HSC Data - Cover Types

Cover Type	Near-bank habitat distance sampled	Mid-channel habitat distance sampled
None	7714	2741
Cobble	8995	449
Boulder	3626	2025
Fine Woody	2711	5
Branches	902	74
Log	130	78
Overhead	388	0
Undercut	3	0
Aquatic Vegetation	246	548
Rip Rap	36	75
Overhead + instream	1950	159

## Transect Placement (study site setup)

### *Juvenile Rearing*

Study sites were established in December 2003. We selected eight habitat study sites in the reaches up- and downstream of Daguerre Dam that, together with the 10 spawning habitat study sites, will adequately represent the various mesohabitat types in each reach. We randomly selected the eight new habitat study sites to insure unbiased selection of the study sites. The reconnaissance work confirmed that the eight additional juvenile rearing sites were feasible considering time and manpower constraints.

Three of the new juvenile rearing study sites are located between the Narrows and Daguerre Dam and the remaining five are located downstream of Daguerre Dam between Daguerre Dam and the confluence with the Feather River (Table 5). Due to the logistical difficulties with accessing and transporting needed equipment above a large hydraulic barrier in the middle section of the Narrows, the study sites were confined to downstream of that barrier. For the sites selected for modeling, the landowners along both riverbanks were identified and temporary entry permits were sent, accompanied by a cover letter, to acquire permission for entry onto their property during the course of the study.

For each study site, a transect was placed at the up- and downstream ends of the site. The downstream transect will be modeled with PHABSIM to provide water surface elevations as an input to the 2-D model. The upstream transect will be used in calibrating the 2-D model - bed roughnesses are adjusted until the water surface elevation at the upstream end of the site matches the water surface elevation predicted by PHABSIM. Transect pins (headpins and tailpins) were marked on each river bank above the 10,000 cfs water surface level using rebar driven into the ground and/or lag bolts placed in tree trunks. Survey flagging was used to mark the locations of each pin. Horizontal benchmarks were established at each site for total station placement when collecting bed topography data. The precise northing and easting coordinates and vertical elevations of two horizontal benchmarks were established for each site by the U.S. Bureau of Reclamation using dual frequency survey-grade differential GPS. The elevations of these benchmarks was tied into the vertical benchmarks on our sites using differential leveling. Collection of site bed topography data relative to these values will be used primarily to enable the incorporation of bed topography data collected for the Yuba River by the U.S. Army Corps of Engineers using LIDAR technology and boat traces. This incorporated data will allow greater refinement of the bed topography for each study site. This approach will also enable establishing the location and orientation of the sites and their bed elevations and water surface elevations relative to data that is concurrently being collected by other entities. This will facilitate the sharing and comparison of data for the various studies being conducted on the Yuba River.



Table 5  
Sites Selected to Model Spring/fall-Run Chinook Salmon and Steelhead/Rainbow Trout Rearing

Site Name	Reach	Site Mesohabitat Types <sup>11</sup>
Narrows	Above Daguerra	FWP, FWRu
Rose Bar	Above Daguerra	BCP
U.C. Sierra	Above Daguerra	BCRi, BCG, BCP, SCRi (2), SCRu, SCP
Timbuctoo	Above Daguerra	BCRu (2), BCRi (2), BCG, BCP, SCRu (3), SCRi, SCG, SCP (2)
Highway 20	Above Daguerra	BCRi, BCP, BCG, SCRu, SCRi
Island	Above Daguerra	BCRu, BCG, BCP (2), SCRu, SCRi
Hammond	Above Daguerra	BCRu
Diversion	Above Daguerra	BCRu
Upper Daguerra	Below Daguerra	BCRu(2), BCRi
Lower Daguerra	Below Daguerra	BCRu, BCRi
Pyramids	Below Daguerra	BCRu, BCRi, BCG
Hallwood	Below Daguerra	BCRu, BCRi
Lower Hallwood	Below Daguerra	BCP, BCG
Plantz	Below Daguerra	BCRu, BCG
Whirlpool	Below Daguerra	BCP
Side-Channel	Below Daguerra	SCRu, SCP
Sucker Glide	Below Daguerra	FWG
Railroad Bridge	Below Daguerra	FWRu, FWP

### Hydraulic and Structural Data Collection

#### *Spawning*

Hydraulic and structural data collection for all 10 study sites was nearly completed in early FY 2004<sup>12</sup>. The data collected at the inflow and outflow transects include: 1) WSEL, measured to the nearest 0.01 foot at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling); 2) wetted streambed elevations determined by

<sup>11</sup>Lack of a number in parenthesis indicates one unit for that mesohabitat type in the site.

<sup>12</sup> The only data that remains to be collected is the stage of zero flow for the downstream transect of nine of the sites. This work was delayed until flows were low, and should be completed in the fall of 2005.

subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bankfull discharge surveyed to the nearest 0.1 foot; 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate and cover classification at these same locations (Tables 1 and 2) and also where dry ground elevations were surveyed. Data collected between the transects include: 1) bed elevation; 2) northing and easting (horizontal location); 3) cover; and 4) substrate. These parameters are collected at enough points to characterize the bed topography, substrate and cover of the site.

We have used two techniques to collect the data between the up- and downstream transects: 1) for areas that were dry or shallow (less than 3 feet), bed elevation and horizontal location of individual points were obtained with a total station, while the cover and substrate were visually assessed at each point; and 2) in portions of the site with depths greater than 3 feet, the ADCP was used in concert with the total station to obtain bed elevation and horizontal location. Specifically, the ADCP was run across the channel at 50 to 150-foot intervals, with the initial and final horizontal location of each run measured by the total station. The WSEL of each ADCP run was measured with the level before starting the run. The WSEL of each run is then used together with the depths from the ADCP to determine the bed elevation of each point along the run. Velocities at each point measured by the ADCP will be used to validate the 2-D model. To validate the velocities predicted by the 2-D model for shallow areas within a site, depth, velocities, substrate and cover measurements were collected along the right and left banks within each site by wading with a wading rod equipped with a Marsh-McBirney<sup>R</sup> model 2000 or a Price AA velocity meter. The horizontal locations and bed elevations were determined by taking a total station shot on a prism held at each point where depth and velocity were measured. A minimum of 25 representative points were measured along the length of each side of the river per site. Water surface elevations have been measured at low, medium, and high flows for all 10 study sites. Discharge measurements for the above WSELs were made on all sites except Hallwood and Plantz<sup>13</sup>. Velocity sets have been collected for the transects at all ten study sites. Depth and velocity measurements were made using a boat-mounted ADCP and by wading with a wading rod equipped with a Marsh-McBirney<sup>R</sup> model 2000 or a Price AA velocity meter. A tape or an electronic distance meter were used to measure stations along the transects. Substrate and cover along the transects were determined visually. Dry bed elevations and substrate and cover data along the transects have been collected, and vertical benchmarks have been tied together for all of the study sites.

We collected the data between the up- and downstream transects by obtaining the bed elevation and horizontal location of individual points with a total station, while the cover and substrate were visually assessed at each point. Bed topography data have been collected for all of the study sites. Bed elevations, substrate and cover data for portions of the sites over 3 feet in depth have been collected using the ADCP and total station for all of the study sites. All of the area of the sites was

---

<sup>13</sup> We will be using the Marysville gage (USGS No. 11421000) flow for the discharge for these two sites.

shallow enough that the underwater video has not been needed to collect substrate and cover data; instead the substrate and cover data were directly visually determined. Shallow validation velocity data collection for all of the study sites have been completed.

### ***Juvenile Rearing***

Vertical benchmarks (lagbolts in trees) were established and water surface elevations collected at all eight juvenile rearing sites at low, medium, and high flows. Because Diversion, Whirlpool, and Side Channel study sites do not contain the entire Yuba River flow, discharges were measured at each of these sites for each of the water surface elevations. Velocity sets have been collected for the transects at all eight study sites. Depth and velocity measurements were made using a boat-mounted ADCP and by wading with a wading rod equipped with a Marsh-McBirney<sup>R</sup> model 2000 or a Price AA velocity meter. A tape or an electronic distance meter were used to measure stations along the transects. Substrate and cover along the transects were determined visually, with the exception of Narrows site, which will require the use of underwater video. Dry bed elevations along the transects have been collected for all eight study sites. Substrate and cover data along the transects have been collected for all eight study sites, except for the deep water portions of Narrows, Rose Bar, Sucker Glide and Railroad sites. In addition, the vertical benchmarks were tied together at all eight sites. The stage of zero flow for the downstream transect has been determined for three of the eight sites.

We have collected the data between the up- and downstream transects by obtaining the bed elevation and horizontal location of individual points with a total station, while the cover and substrate are visually assessed at each point. Bed topography data collection has been completed for all of the study sites, with the exception of the Narrows site and parts of the Rose Bar and Sucker Glide sites. Bed elevations, substrate and cover data for portions of the sites over 3 feet in depth have been collected using the ADCP and total station for all of the study sites, with the exception of Narrows site. All of the study sites, with the exception of the Narrows site, were shallow enough that the underwater video has not been needed to collect substrate and cover data; instead the substrate and cover data were directly visually determined. In the case of the Narrows site, bed elevations, substrate and cover data for portions of the site over three feet have been partially completed. The deep water conditions in the Narrows site required the use of underwater video to collect the substrate and cover data. Shallow validation velocity data collection for six of the eight study sites has been completed. We anticipate completing the hydraulic and structural data collection for all eight juvenile rearing study sites in early FY 2005.

## **Hydraulic Model Construction and Calibration**

### ***Spawning***

Data for three of the spawning sites has been compiled and checked.

# CLEAR CREEK

## Habitat Suitability Criteria Development

### *Spawning*

Staff of the Red Bluff Fish and Wildlife Office have been collecting spring-run chinook salmon and steelhead/rainbow trout spawning habitat suitability criteria during their biweekly snorkel surveys of Clear Creek. For HSC data collection, all of the active redds (those not covered with periphyton growth) which could be distinguished were measured. The location of each redd was marked with a GPS unit. The location of each redd found in our study site was determined with a total station. Data were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction. This location was generally about 2 to 4 feet upstream of the pit of the redd; however it was sometimes necessary to make measurements at a 45 degree angle upstream, to the side, or behind the pit. The data were almost always collected within 6 feet of the pit of the redd. Depth was recorded to the nearest 0.1 foot (ft) and average water column velocity was recorded to the nearest 0.01 ft/second. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2 inches) at three locations: 1) in front of the pit; 2) on the sides of the pit; and 3) in the tailspill. Substrate embeddedness data were not collected because the substrate adjacent to all of the redds sampled was predominantly unembedded. The substrate coding system used is shown in Table 1. Since data were collected within 2 weeks of redd construction (as a result of the biweekly surveys) it is likely that the measured depths and velocities on the redds are similar to those present during redd construction. To date, complete HSC data (depth, velocity and substrate) have been collected on 94 spring-run chinook salmon redds and 86 steelhead/rainbow trout redds.

## Field Reconnaissance and Study Site Selection

### *Spawning*

A reconnaissance of Clear Creek between Whiskeytown Reservoir and the confluence with the Sacramento River was conducted to delineate the study reaches where two-dimensional (2-D) habitat modeling will be undertaken for fall-run chinook salmon, spring-run chinook salmon and steelhead/rainbow trout spawning and fry and juvenile rearing. Based on this review, a total of three reaches were delineated: the upper alluvial reach, the canyon reach, and the lower alluvial reach. Spring-run chinook salmon and steelhead spawn in the upper two reaches, while fall-run chinook salmon spawn in the lower reach. Because of the number of reaches involved, it was determined that the data collection will have to be divided into three phases. The first phase of work will investigate spawning and encompass the upper alluvial and canyon reaches which extend between Whiskeytown Reservoir and the lower end of the canyon reach. Field reconnaissance in FY 2004 investigated potential study sites in these two reaches. Prior to conducting the field reconnaissance, several years of data on spring-run chinook salmon and steelhead/rainbow trout spawning were reviewed to determine the locations where the greatest

numbers of redds had been observed. This data was plotted up in GIS and the locations where the greatest numbers of redds has been observed were selected for reconnaissance. The field reconnaissance was conducted in October 2003 and the various potential study sites assessed for 2-D modeling potential and accessibility. Considering time and manpower constraints, the reconnaissance work narrowed the list of potential sites to the five study sites that will be modeled. These sites are Spawning Area 4, Peltier, Need Camp, Indian Rhubarb, and Upper Placer. Due to the depth of water and lack of spawning habitat in the middle portion of Upper Placer site, this site was later split into two sections that excluded the middle portion of the site.

### **Transect Placement (study site setup)**

The five study sites were established in February 2003. For the sites selected for modeling, the landowners along both riverbanks were identified and temporary entry permits were sent, accompanied by a cover letter, to acquire permission for entry onto their property during the course of the study.

For each study site, a transect has been placed at the up- and downstream ends of the site. The downstream transect will be modeled with PHABSIM to provide water surface elevations as an input to the 2-D model. The upstream transect will be used in calibrating the 2-D model - bed roughnesses are adjusted until the water surface elevation at the upstream end of the site matches the water surface elevation predicted by PHABSIM. Transect pins (headpins and tailpins) were marked on each river bank above the 1,000 cfs water surface level using rebar driven into the ground and/or bolts placed in tree trunks. Survey flagging was used to mark the locations of each pin.

### **Hydraulic and Structural Data Collection**

#### ***Spawning***

Vertical benchmarks (lagbolts in trees or bedrock points) were established and water surface elevations collected at all five spawning sites at low and medium flows. High flow water surface elevations were also collected at the Upper Placer site. Velocity sets have been collected for the transects at all five study sites. Depth and velocity measurements were made by wading with a wading rod equipped with a Marsh-McBirney<sup>R</sup> model 2000 or a Price AA velocity meter. A tape or an electronic distance meter were used to measure stations along the transects. Substrate and cover along the transects were determined visually. Dry bed elevations and substrate and cover data along the transects have been collected and the vertical benchmarks were tied together at all five sites.

We have collected the data between the up- and downstream transects by obtaining the bed elevation and horizontal location of individual points with a total station, while the cover and substrate are visually assessed at each point. Bed topography data collection has been completed for three of the study sites, with portions of the Peltier and Need Camp sites still incomplete.

Validation velocity data collection for all five study sites have been completed. We anticipate completing the hydraulic and structural data collection for all five spawning study sites in early FY 2005. We then plan on selecting additional juvenile rearing sites needed to represent the habitat types found in the same two reaches as the first phase spawning sites. Hydraulic and structural data collection on the juvenile rearing sites will begin in FY 2005.

## REFERENCES

- Earley, J.T. and M. Brown. 2004. Accurately estimating abundance of juvenile spring chinook salmon in Battle and Clear Creeks. In: Getting Results: Integrating Science and Management to Achieve System-Level Responses. 3<sup>rd</sup> Biennial CALFED Bay-Delta Program Science Conference Abstracts. October 4-6, 2004. Sacramento, CA.
- McReynolds, T., P. Ward and C. Harvey-Arrison. 2004. Utility of juvenile salmon growth models for discrimination of Central Valley spring-run chinook in California. In: Getting Results: Integrating Science and Management to Achieve System-Level Responses. 3<sup>rd</sup> Biennial CALFED Bay-Delta Program Science Conference Abstracts. October 4-6, 2004. Sacramento, CA.
- Rubin, S.P., T.C. Bjornn and B. Dennis. 1991. Habitat suitability curves for juvenile chinook salmon and steelhead development using a habitat-oriented sampling approach. *Rivers* 2(1):12-29.
- U. S. Fish and Wildlife Service. 2003. Flow-habitat relationships for steelhead and fall, late-fall and winter-run chinook salmon spawning in the Sacramento River between Keswick Dam and Battle Creek.